



Learning from an electromobility living lab: Experiences from the Estonian ELMO programme



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ABSTRACT

The article provides insights into the setting up of the Estonian electromobility pilot programme (ELMO) and evaluates its first outcomes. The uniqueness of the Estonian case lies in its nationwide scale and extremely fast implementation. In the middle of 2010 the government initiated the ELMO programme as part of the larger project for using excess carbon emission quotas for emission reduction projects. The programme also contained the building of the first nationwide electric car quick charging network in the world. This paper focuses on the underlying objectives at different spatial levels and the setting up of the feedback mechanisms according to the living lab framework. In order to provide recommendations for effective policy measures for fostering the diffusion of radical innovations like electromobility, a holistic view proves to be essential. The case study aims to offer overview of experiences that either could be copied or should be avoided when planning and executing electromobility pilot projects in follower countries.

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1. Introduction

Road transport generates about one-fifth of the EU's CO₂ emissions, with passenger cars responsible for around 12%.¹ This makes it the second most important source of greenhouse gases. Although there have been significant improvements over recent years in vehicle technology, these have not been enough to neutralise the effect of increases in road traffic intensity. Electric cars, as an alternative to traditional internal combustion engine cars, have been discussed and promoted in several countries. See, for example, Liu and Kokko (2013) about China, Propfe et al. (2013) for Germany, Feng and Figliozzi (2013) about USA, etc. It is expected that wider diffusion of electric cars would bring along environmental improvements in the transport sector, as well as provide a solution to alleviate oil demand and in the case of several countries, decrease dependence on imported energy (European Commission, 2011). In the scenario analysis by Roland Berger Strategy Consultants, it has been suggested that taking into consideration the market trends in the automotive industry, in the most positive case, electric vehicles will account for around 10% of new vehicle sales by 2025 (Kalmbach et al., 2011). When it comes

to absolute numbers then naturally larger countries also form the top of the electric car sales rankings (International Energy Agency, 2013). However, smaller countries like Estonia, Norway and the Netherlands are placed on top by the penetration ratio of electric cars among the total registered passenger car fleet.

The aim of the paper is to provide insights into the unique experiment of introducing electric cars by the Estonian government. In March 2011 the Estonian government approved the selling of 10 million unused emission allowance units (Assigned Amount Units—AAUs)² to the Japanese conglomerate Mitsubishi Corporation. With support of this transaction, during 2012–2013 the Estonian nationwide electric vehicles' charging network was built, the electric vehicle purchase grant scheme for private buyers was launched in order to foster the introduction of electric cars, and a demonstration fleet of 507 Mitsubishi i-MiEV electric cars was distributed for free to social workers around Estonia. As a result, during a few months the electric cars were spread across the whole country.

The flexibility, speed of implementation of novel solutions and the feasible nationwide coverage of a small country make Estonia a perfect testing ground. Although the implementation started without thorough prior planning, these actions and actors

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¹ European Environment Agency (EEA) [<http://www.eea.europa.eu/themes/transport>].

² Assigned Amount Unit (AAU) is a tradable 'Kyoto unit', known also as 'carbon credit' or 'CO₂ quota', representing an allowance to emit greenhouse gases comprising one metric tonne of carbon dioxide equivalents.

	Environmental	Socio-economic	Technological
Global	Reducing CO ₂ emissions to mitigate global climate change	Improving welfare by fostering global sustainable growth (economically and environmentally)	Fostering transformative innovations in transport systems in order to achieve paradigm shift in living arrangements
Regional (European)	Reducing CO ₂ emissions in Europe in order to contribute to global climate change mitigation	Improving regional welfare by maintaining and improving the region's (Europe's) competitiveness in global economy	Fostering transformative innovations in the region by supporting the development and uptake of low-carbon solutions in mobility, including increasing the share of renewable energy used in transport
National	Reducing CO ₂ emissions in a country in order to contribute to global climate change mitigation	Improving national welfare by maintaining and improving a country's position in the global economy	Fostering transformative innovations by leading the uptake of low-carbon solutions (creating lead markets), including increasing the share of renewable energy used in transport
Municipal	Reducing CO ₂ emissions in a city in order to improve local air quality and reduce transport noise	Improving life quality and wellbeing of local citizens by providing a healthier living environment at a reasonable cost	Fostering transformative innovations by leading the uptake of low-carbon solutions in the local transport system
Company	Contributing to CO ₂ emission reduction by offering products and services with a lower negative environmental impact	Maintaining and improving competitiveness of the company by continuous monitoring and improvement of processes for cost-efficient solutions	Leading the development of low-carbon solutions (for the transport sector) in order to maintain and improve a company's competitiveness

Fig. 1. Matrix of objectives for fostering transformative environmental innovations, the case of transport in Europe. (authors' own compilation).

combined to create a system which allows analysing this country-level experiment in the living lab framework.

The roots of the Estonian electromobility programme, as often in the case of national CO₂ reduction policy actions, date back to the Kyoto Protocol³ that entered into force in 2005, and the global agreement on creating the emissions trading systems (ETs).⁴ The situation in Estonia was unusual and extraordinary. Based on emissions in 1990, Estonia was assigned 196 million AAUs (e.g. 39 million AAUs annually)⁵ and took responsibility to reduce greenhouse gas emissions by 8% by 2012 compared to the base year 1990. Due to the major structural changes in national economy, accrued renewable energy production methods, and several energy efficiency projects implemented in Estonia since 1990, only around 56% of it was actually used by existing production units. The excess amount (around 85 million AAUs) was available for trading according to the Green Investment Scheme (GIS), a financing mechanism where financial resources that come from trading the country's CO₂ quotas under the Kyoto Protocol are channelled into environmental projects that help to cut CO₂ and other greenhouse gas emissions. When it comes to selecting the investment targets, each country sets its own priorities. At the time when the programme was initiated, projects falling under the scope of the Directive 2003/87/EC, lasting until the end of 2012 and

in compliance with the Estonian National Allocation Plan for 2008–2012 (NAP)⁶ were authorised to use funding from excess AAUs.

The amount of excess AAUs made Estonia one of the biggest tenderers on the market, where, due to oversupply of about 10–20 times,⁷ buyers usually set the terms. As the project to which the income from the AAUs will be directed is chosen by the buyer (which may be a country or a corporation), the negotiation process goes in parallel with the development of project proposals by the tenderer's ministries. For Mitsubishi, an electric car manufacturer, it was naturally a strategic decision to choose this deal in the market conditions of vast oversupply of AAU quotas.

The electromobility project was already the fourth deal that Estonia made with Mitsubishi Corporation. The revenue from previous AAU sales to Mitsubishi had been targeted at renovation of the state and local government buildings for the purpose of energy conservation. Estonia has also used excess AAUs for several other projects ranging from supporting the market entry of renewable energy technologies to new electric trams in the capital city, Tallinn, and biogas buses in Tartu. However, the electromobility programme is one that stands out due to its cross-national nature.

For Estonia, the second rationale behind choosing the deal with Mitsubishi Corporation and launching the electromobility programme was derived from the EU Directive⁸ about reducing the

³ Kyoto Protocol [http://unfccc.int/key_documents/kyoto_protocol/items/6445.php].

⁴ The EU Emissions Trading System (EU ETS) [http://ec.europa.eu/clima/policies/ets/index_en.htm].

⁵ United Nations Framework Convention on Climate Change. Report of the review of the initial report of Estonia. 14 November 2007. [<http://unfccc.int/resource/docs/2007/irr/est.pdf>].

⁶ National Allocation Plan for 2008–2012. [http://www.envir.ee/orb.aw/class=action=preview/id=1174608/NAP_2008_2012.pdf].

⁷ Anne Sulling in webcast in 2010 [<http://valitsus.ee/et/uudised/video/Ekspertid+kommentaar/-/2/#1002>].

⁸ EU Directive 2003/87/EC [http://ec.europa.eu/energy/renewables/targets_en.htm] and [<http://eur-lex.europa.eu/LexUriServ/LexUriServ.do?uri=DD:15:07:32003L0087:ET:PDF>].

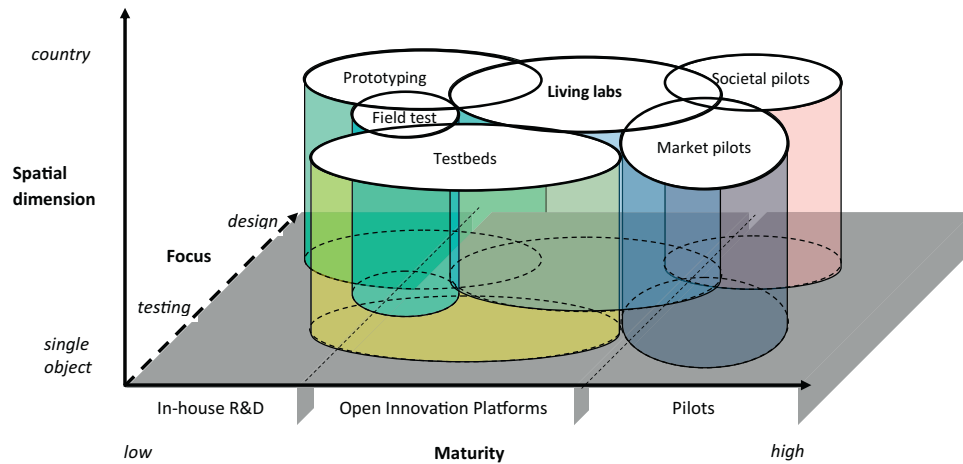


Fig. 2. Test and experimentation platforms in additional spatial dimension.

Authors' own elaboration, based on Ballon et al. (2005).

use of fossil fuels in the transport sector and related targets in the Estonian Transportation Development Plan.⁹ The Plan set the goal to achieve 10% energy consumption in transportation from renewable sources by 2020. This is planned to be achieved by blending biofuels, supporting green public transportation, raising eco-driving awareness and last but not least, fostering diffusion of electromobility. As in Estonia it is easier to produce electricity from renewable sources than bend liquid biofuels, the electromobility could potentially be a viable alternative.

The paper is organised as follows. First, we introduce the global, regional and national framework conditions which have given a boost to carbon reduction initiatives and more precisely sustainability-driven innovations in transport. Next, we will look in more detail at the opportunities that the global carbon emissions' trading system has created and particularly at the case where Estonia has chosen to use excess emission allowances to create the electromobility pilot programme. In the following section we provide an overview of the main objectives that exist at different levels regarding supporting diffusion of these kinds of radical innovations. Subsequently, we give a brief overview about one of the experimentation platforms -the living lab- and describe the setup process and feedback mechanisms of the Estonian electromobility programme in this framework. Finally, based on the experiences of the first years of the Estonian pilot programme we draw preliminary conclusions and set a number of research questions for further empirical studies.

2. Material and methods

Dijk et al. (2013) have highlighted the importance of interaction between vehicle engine technology and the car use context. In Estonian case the social care workers' demonstration fleet gives us the opportunity to analyse different socio-economic and technical aspects of using electric cars. The technical aspects are valuable inputs, among others, for car and battery manufacturers, developers of charging stations, and designers of customer management interfaces. Additionally, the government can test the impact of innovation policy measures as they need to build a holistic approach for this extremely interdisciplinary subject and academic

researchers gain access to unique data sets, which could hardly be requested from private car users without such demonstration project.

In this article we explore the set up process and objectives of different actors of the Estonian electromobility pilot programme. We provide first insights into what has gone as expected and where the drawbacks have been experienced, though the period has been too short to draw definitive conclusions. We believe that the lessons learned during the first years of this experiment would be of interest to any other country willing to introduce electromobility or other sustainability-driven transformative innovation in the transport sector.

Coenen et al. (2012) have contended the prevailing literature stream on sustainability transitions to be spatially naïve, overlooking the aspect where transitions take place. Deriving from their argumentation, we enlist the objectives of fostering sustainable transport at different spatial levels (Fig. 1).

At global level, the ultimate goal, or it could even be said the inescapable necessity, is to improve welfare and achieve sustainable growth, both economically and environmentally. For tackling the challenges like climate change we need international cooperation, mutual agreement and coherence in CO₂ reduction policies, as well as innovation policies. Wider diffusion of transformative innovations, e.g. using electricity to power personal cars, could play an important role in the new reshaped mobility system and support achieving a paradigm shift in whole living arrangements. However, the exact solutions need not be unified, but at the same time should fit the regional and local conditions.

There is a substantial amount of literature on how policy makers can and should deliberately foster transformative innovations, e.g. Philips (2007), Steward (2012) and others. Scrase et al. (2009) have emphasised that in order to achieve transformative innovation, a culture of purposeful experimentation must be fostered. Such transitions are only possible if a critical mass of social actors is ready to conceive and commit to radical transformative change at an early stage, well before the outcome seems inevitable. This involves thinking beyond the incremental optimisation of existing systems—as typically encouraged by dominant everyday political and commercial pressures (Scrase et al., 2009).

When creating matrices, like the one we are suggesting in Fig. 1, it can always be disputed how the different, sometimes conflicting, objectives should be classified. Perez (2010), for example, discusses the technological innovation driven shifts in 'techno-economic paradigm' and their influence on institutional and social change, while Steward (2012) suggests 'socio-technical' paradigms, which

⁹ Estonian Transport Development Plan 2006–2013 (Transpordiarendukava 2006–2013). [<https://www.riigiteataja.ee/aktiilisa/0000/1278/4604/12784610.pdf>] and Estonian Transport Development Plan 2014–2020 (proposal) [<https://valitsus.ee/UserFiles/valitsus/et/valitsus/arendukavad/arendukavade-koostamise-ettepanekud/Transpordi%20arendukava%202014-2020%20koostamise%20ettepanek.pdf>].

emphasise more the role of different actors and networks, and addresses the challenge of achieving transformative innovation by supporting consumption and end use. He argues that “it avoids the pitfalls of selectively predetermining particular technologies in advance and provides a far more plausible framework for the engagement of consumers in the innovation process” (Steward, 2012). However, when discussing the objectives of transformative innovations generally, we suggest using the ‘socio-economic’ dimension because eventually the technological development should serve the economic wellbeing of society.

As we described in Fig. 1, the triggering motives behind different policies may be intertwined in multiple ways. Hence the data collection during such experiments should follow a certain system. Additionally, the objectives of the three starting points of the paradigms (environmental, socio-economic, technological), must also be in coherence in spatial dimension. For example, a single object (e.g. a firm) may have good deeds; however it is able to implement them only if they match the values of their clients and other stakeholders. A city government must create a balance between the interests of its citizens as well as the interests of the whole country. The country, on the other hand, primarily serves its people, but in the case of many environmental concerns is responsible also for what takes place in the wider regional and

global context. This intertwined system calls for innovative ideas and solutions that come from outside the traditional single object boundaries—for ‘open innovation’.

The ‘open innovation’ paradigm is replacing the logic of an earlier era, where innovation was inwardly-focused and closed off from outside ideas and technologies (Chesbrough, 2003). Within the last decade several approaches emerged in order to implement open innovation ideas in practice (Chesbrough and Crowther, 2006). End user involvement and co-creation in innovation process are seen as increasingly powerful instruments at all stages of innovation process (von Hippel, 2001). Different open innovation oriented platforms have been developed involving both technology and service providers and end users in different stages of technology design, development and testing. Ballon et al. (2005) introduced the generic term of test and experimentation platforms (TEPs) in order to indicate all facilities and environments for joint innovation including testing, prototyping and confronting technology with usage situations. They distinguished six types of TEPs: prototyping platforms, test beds, field tests, living labs, market pilots, and societal pilots (Fig. 2).

The proposed typology by Ballon et al. (2005) rests on combining three criteria—the technological readiness/maturity, testing focus (technology or design) and degree of openness,

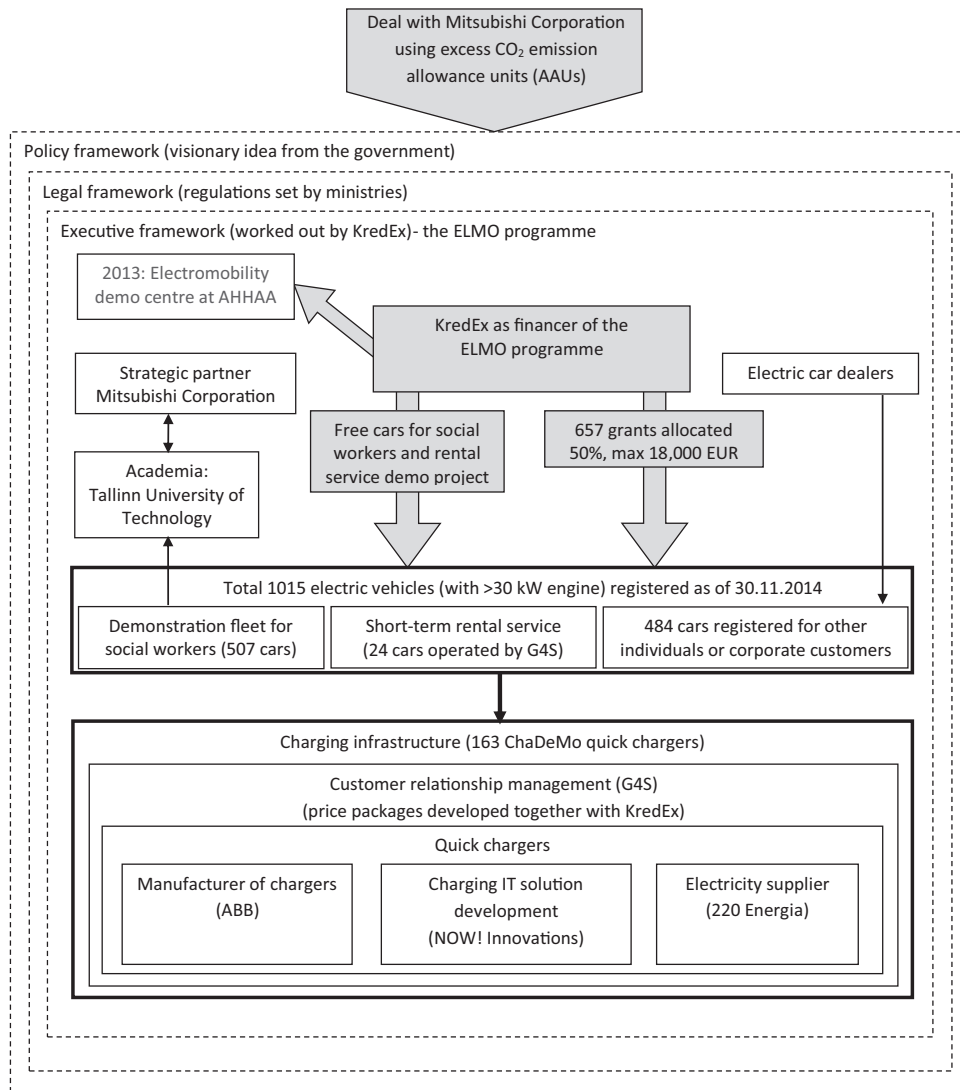


Fig. 3. Framework of the Estonian electromobility pilot programme.

(authors' own compilation).

ranging from in-house activities to open platforms. When following our research interests, distinguishing the spatial dimension also becomes important. In our opinion, pilot projects which cover a country or even bigger region provide significantly more valuable lessons than the experiments which cover only a single object (e.g. hospital, airport, one city). Therefore, in the Fig. 2, the typology of Ballon et al. (2005) was complemented with an additional dimension describing the spatial coverage of suggested test and experimentation platforms.

In the case of electromobility the product prototyping and first field test are already done by car manufacturers by using the traditional test beds of the automotive industry. However, in the case of radical innovations, such as the electrification of the passenger car industry, this is often not sufficient for ensuring social acceptance and market success. There is a need to test these innovative solutions, often a whole system, in the actual user environment and involve all relevant actors in the system development. During last decades the 'living lab' (living innovation laboratory) has obtained growing importance among the different TEPs. Liedtke et al. (2012) have summarised the living lab as "an integrated technological socio-economic approach to enable optimised interaction of production and consumption".

The concept of the living lab was first proposed and developed by W.J. Mitchell, professor of the MIT Media Lab and School of Architecture, with the aim to apply user-centric research methods in real life environments to identify and build prototypes, and to evaluate multiple solutions (Schoorman et al., 2011). A wide range of definitions of the living lab have been proposed depending on the central viewpoints (see overview by Niitamo et al., 2006). With the environment perspective, objects such as technological platforms and user communities come to the forefront. With the methodology perspective, processes such as data transfers and methods for user involvement are highlighted. Based on the intensity of involvement, Niitamo (2009) has suggested five levels of user engagement: (1) users monitored/user data simulation, (2) user participating, (3) user collaborating, (4) user designing, and (5) user producing.

The system perspective puts focus on the living lab as a whole and relations between its interdependent parts (Bergvall-Kåreborn et al., 2009), i.e. describes the living lab as a business network which combines different stakeholders (or actors). Leminen and Westerlund (2008), and later Nyström and Leminen (2011), have identified key actors of collaborative innovation development and innovation networks in the living lab context. They propose four categories of living labs according to the actor who has been the most active in the beginning of the living lab, and later on acted as the driver of the activities: utilizer-, enabler-, provider-, and user and user community-driven. In a utilizer-driven living lab the focus is on developing the firm's products and/or services. Enabler-initiated living labs are projects by public actors in specific region, e.g. in order to solve structural problems within the region. Provider-driven living labs are typically initiated by the activities of developer organizations, such as educational institutes or consultants. User driven living labs are targeted to solve problems perceived in the everyday life of a user or community of users (Nyström and Leminen, 2011).

This typology of living labs is highly useful in choosing the most suitable test and experimentation platform for a specific innovation. It reflects the ecosystem features of the living lab, where a multi-partnered collaboration network of actors exists, also called a Public Private People Partnership, where firms, public authorities and citizens work together (Eriksson et al., 2006). It allows better outlining of motivations of different actors and therefore also supports more grounded policy recommendations.

In the following section we analyse the case of the Estonian electromobility programme in the living lab framework. Aside

from the overview of its creation and development process we also specify the main stakeholders, their objectives and involvement motives. Particular importance is given to the analysis of the role of government in this process as an initiator and facilitator of the living lab. The input has been gathered in discussions with the main actors, as well as by extensive analysis of secondary materials.

3. Results and discussion

The overall goal set for the Estonian electromobility pilot programme ELMO was to promote emission free personal transportation and electric cars in order to achieve a better city environment, energy efficiency and fuel independence. The creation of both the grant scheme and the public quick charging network was coordinated by KredEx.¹⁰ Fig. 3 describes the general framework of the Estonian pilot programme that was mainly set up during 2011–2012. Later, in the middle of 2013, the electromobility demo centre and electric cars' short-term rental service were also launched.

By the end of 2014 we were already able to draw the first conclusions and lessons learned from this experiment. Comparing the Estonian approach for enhancing electromobility with neighbouring Finland and Sweden, we can conclude that the speed of implementation of the electromobility pilot project depends on the vigorous and systemic action of the government. For a better overview of the Estonian electromobility programme, we give a brief description of the role of four private companies, which have significantly contributed to its setup.

3.1. ABB Eesti

ABB Eesti (ABB Estonia) is a subsidiary of the ABB Group, the Zurich based global leader in power and automation technologies. The company operates in approximately 100 countries and its history spans over 120 years. ABB's success has been driven particularly by a strong focus on research and development. Today, ABB stands as the largest supplier of industrial motors and drives, the largest provider of generators to the wind industry, and the largest supplier of power grids worldwide.¹¹ In the Estonian electromobility programme ABB Eesti is the supplier of quick chargers for the public cross-national network. The Estonian government will remain the owner of the public charging infrastructure through KredEx for at least five years. KredEx, as a financing institution, will buy a full service from ABB, which is also responsible for the performance of its selected subcontractors—software platform developer Now! Innovations and network operator G4S.

3.2. G4S Estonia

G4S Estonia is a subsidiary of G4S, an international market leader in security-related services represented in more than 125 countries worldwide. G4S participated in the procurement tender as a subcontractor to ABB Eesti. G4S Estonia, the operator for the quick charging network, is required to ensure that the charging stations remain operational at all times. They offer 24 h technical support and also customer service by 24/7 customer support phone. To use the quick charger, it is first necessary to enter into a contract with G4S. This can be done at a self-service platform (SSP)¹² if you are a private customer, or by e-mail or letter

¹⁰ KredEx [<http://www.kredex.ee>].

¹¹ ABB Group website [<http://www.abb.com>].

¹² ELMO Self Service Portal [<http://klient.elmo.ee>].



Fig. 4. Spatial distribution of electric vehicles and quick chargers across counties data presentation: total number of cars (chargers); percentage of cars (chargers). Source: authors' own compilation.

if you are a business customer. After the contract is signed you can start using ELMO RFID card and ELMO mobile application. G4S is also responsible for organising customers' billing. Paying for the quick charging service is convenient—if you have signed a contract to use the ELMO quick charging service, you do not have to think about the payment every time you charge, but you will get a monthly bill via e-mail for the previous months' services. You can check the billing status at a SSP and also pay the bills there.

3.3. Now! Innovations

NOW! Innovations is the system developer for the quick chargers, their maintenance and billing solutions. The Park NOW! platform is suitable for parking, electric vehicle charging, bike rentals and other mobility needs. It is an Estonian company which experience of mobile parking and other transport industry solutions dates back to 2003. Since 2006 NOW! Innovations has been the world's fastest expanding mobile parking software provider, currently operating in a commercial or pilot stage in nine countries on three different continents and having processed over 10 million parking transactions by almost half a million users.

3.4. 220 Energia

220 Energia Ltd.¹³ is an electricity trading company, based on Estonian and Finnish private capital. Although the company is not old, the owners have long-term experience in the Nordic electricity market¹⁴ and good knowledge of electricity trade in general. This, together with low personnel costs due to good IT solutions, allows offering electricity to commercial as well as private consumers at very competitive prices. 220 Energia was chosen to be the supplier of renewable energy for the electromobility programme by KredEx through an open bid. The electricity under this deal comes from biogas produced at a local waste plant.

As the user experience plays a crucial part in accepting new technologies and ensuring their wider diffusion, the negative

myths surrounding electric vehicles were disproved by offering possibilities for test driving. On 28 June 2013, the science centre Ahhaa in Tartu opened the very first electric car demo centre¹⁵ in Estonia. The exhibition offers a thorough, but simple overview of how the engines and transmission systems of electric cars work, and describes the charging process in detail. It is possible to compare electric engines and internal combustion engines and to test drive an electric car (Nissan Leaf or Mitsubishi i-MiEV). The main exhibit is an interactive electric car simulator, which allows you to simulate a car ride by operating the steering wheel, pedals, gearbox and various switches. A realistic image that changes with your every action will appear on the windscreen. You can also take a closer look at the charging devices—both standard and quick chargers.

We suggest that new business models that offer first experience with new technologies, without requiring immediate ownership, should also be supported by government. As an example, since July 2013, as part of the national electromobility programme, in two bigger cities—Tallinn and Tartu, the short-term rental service ELMO Rent¹⁶ also became available. These rental cars are equipped with 24 h GPS surveillance technology, which enables customers to locate on a smartphone the closest free car. The ELMO Rent is operated by G4S, the company which is also operating the public quick chargers' network. The idea is to promote electric cars by reducing users' fears of new technologies. Anyone can try and use an electric car without making a big initial investment or binding long-term commitment. During the pilot project 24 electric cars will be available for hire, 16 of them Nissan Leaf and 8 Mitsubishi i-MiEV. To use this service, you need to register in the self-service portal. You will be charged per minute of use, e.g. you pay for the time that you actually use the car. The service operations are conducted via special mobile phone application. The data gathered by rental cars still remain to be analysed. The service has got very positive feedback from customers, the amount of available cars

¹⁵ Demo centre [<http://www.ahhaa.ee/en/permanent-exhibition/aha-electric-cars>].

¹⁶ KredEx press release from 11.07.2013 [<http://elmo.ee/elmo-short-term-car-rental-is-inviting-everyone-to-try-driving-an-electric-car>].

¹³ 220 Energia Ltd. website [<http://www.220energia.ee>].

¹⁴ Nordic electricity market [<http://www.nordpoolspot.com>].

became the main limiting factor already during the first quarter. The positive customer acceptance can be interpreted in two ways—first, that it builds ground for faster market uptake of electric cars, and second, that in personal transport there is readiness for diffusion of radically new business models.

In order to avoid the ‘chicken and egg’ problem in case of the infrastructure-dependent radical innovations, the governmental support measures should cover both aspects. As electromobility is directly connected to the energy regime, customers also need to accept the new energy re-charging technologies and business models. The limited driving range with one charging has been considered as the main drawback by most customer surveys. Therefore, the priority in the Estonian electromobility strategy has been to deal with range anxiety of the first electric car users. The strength of the Estonian approach in developing the infrastructure lies in its nationwide quick chargers network (163 quick chargers that follow the standard of first cars—CHAdEMO), which at this point is unique in the world. The spatial distribution of electric vehicles and quick chargers across the country is presented in Fig. 4.

For launching the quick charging infrastructure, KredEx organised a public tender for the charging technology, central network management system and five-year full service contract for network operating services, including the 24/7 central customer support. Offers were made by ABB Ltd., Hitachi Ltd. from Japan, a joint proposal by the French Citelum and Japanese Marubeni Corporation, and also a joint proposal by Ericsson Eesti Ltd. and Fortum Asiakaspalvelu Oy. Hitachi Ltd., however, did not qualify due to incomplete documentation. The winning offer for the construction of the quick charging network of electric cars was made by ABB Ltd. with the price of 6.6 million euros plus VAT. The built solution is supported by IT platform that allows real-time online access to charging information, both to consumers and for network maintenance (Fig. 5).

Next we summarise the feedback mechanisms that were planned and created within the framework of the Estonian electromobility programme. Based on the car user, data gathering methods can be outlined as follows.

(1) Social workers' cars are equipped with GPS/GPRS data loggers, which inform about:

- charging patterns (general charging frequency, separately quick and slow charging, etc.);
- patterns of using car's electric gadgets (heating, lights, etc.);
- suitability of electric cars for offering social services;
- general need for transportation in the social service sector.

(2) Individuals and companies who apply for the car purchase grant provide:

- data submitted on the grant application;
- annual reporting of passage in order to ensure that they use only electricity produced from renewable sources (for the calculation of green certificates).

Additionally, the smart solutions integrated into the public quick charging infrastructure and web-based customer interface (self-service portal) allows specific analysis of charging patterns at aggregated and disaggregated level. Data can be gathered for analysing the technical performance, as well as for calculating the economic viability.

(1) Electro-technical data from the public quick charging infrastructure:

- number of chargings, time of charging (morning/day/night);
- average charging volume (kWh);
- electricity use of chargers, electricity loss of chargers, technical durability (charger or battery), maintenance needs, etc.

(2) Business data from the public quick charging infrastructure:

- popularity of different consumer packages;
- change requests of consumer packages;
- popularity and occupancy across different charging locations, etc.



Fig. 5. The real-time map of nationwide quick charging network.

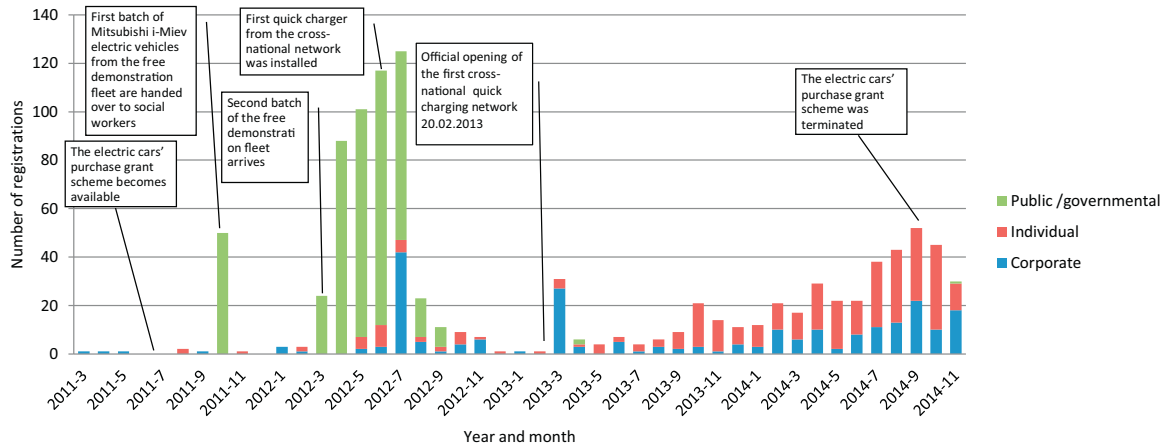


Fig. 6. Registration dynamics of electric cars in Estonia (01.03.2011–30.11.2014).

Source: Authors' own compilation, based on data from Estonian Road Administration [<http://www.mnt.ee/index.php?id=10797>] accessed 5.12.2014.

The above list of data gathering options in the living lab framework is definitely not exhaustive as the possibilities for information collection are much wider than those used for this analysis. Several individual components of the above data are also being collected and studied in other countries, but we believe that creating a holistic system of feedback mechanisms by the principles of the living lab is the most resourceful approach. Later, when the short-term rental service gains ground, it can be used to explain the need for personal mobility even more generally, and perhaps even challenge the old business models (e.g. need for car ownership).

3.5. Outcomes of the ELMO programme

By the end of November 2014, there were 1015 electric cars registered in Estonia (with an engine 30 kW or more). We have excluded the cars with a lower engine capacity because they are not considered a competitive alternative to driving an internal combustion engine car on the road. The registration dynamics of electric vehicles can be observed in Fig. 6, where the main peaks at the beginning of the programme represent the batches of social workers' cars that arrived from Mitsubishi. The legal entities category contains also some cars from the demonstration fleet because one of the social care service providers is a fully government-owned company.

It can be seen that the interest of individual and corporate buyers rose when the actual setup of the public quick chargers network started, and later on, when the word about positive experiences spread and the resources for the subsidy were starting to end.

It must be taken into account that the activities of the programme are reflected in the official registration data with a short time lag. For example, processing of the applications at KredEx takes some time; often the cars are also not immediately available but must be ordered from the factory, etc. This is clearly reflected also on the following Fig. 7, where the applications for purchase grants peaked in July 2014 (as the grant was terminated in the first week of August), but the registrations follow with a time lag of up to three months.

What we also can observe from Fig. 7 is that, although the Estonian purchase grant was one of the most generous incentives in Europe from the start, at the beginning the interest was quite low and almost everybody who applied for the grant also received it. The announcement in the media in July 2014 that the resources will soon be finished caused a rush that can rarely be seen in the car market.

The Estonian electromobility programme involves or has involved four out of five user engagement levels suggested by Niitamo (2009). As explained before, depending on the user type, they were and continuously will be monitored. This monitoring system involves modern ICT solutions and is automated. The social

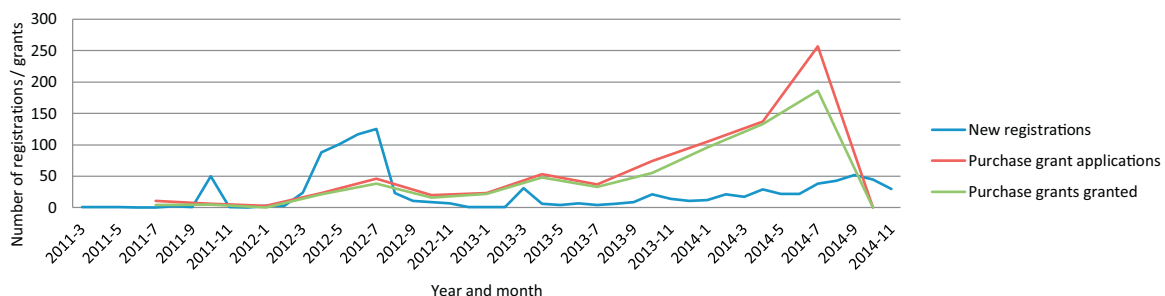


Fig. 7. Registration dynamics of electric cars in Estonia (01.03.2011–30.11.2014).

Source: Authors' own compilation, based on data from Estonian Road Administration [<http://www.mnt.ee/index.php?id=10797>] accessed 5.12.2014.

workers' demonstration fleet is a good example of users participating in the living lab. Collaboration with users (and other stakeholders) took place, for example, when the locations for prospective quick chargers were chosen through public poll. Inside the current framework it is hard to see any good option for the user to be also the producer, but these opportunities may rise when the electric vehicle and its battery become an important part of the smart electricity grid.

The feedback mechanisms of the Estonian electromobility programme, which are typical to living labs, provide valuable information and each of the aspects can be analysed separately in more detail or in combination. Among others, an interesting fact is that out of the 163 public quick chargers, the nine most actively used ones are located in Tartu, not in the capital city, Tallinn. The charger-per-electric-car ratio (can be calculated from Fig. 4) does not justify that. One of the reasons behind active chargers' use in Tartu could be that in Tartu there are several electric taxis, which, on the other hand, is a privately initiated service and not part of the ELMO programme.

In May 2013 the first Estonian electric car users' survey¹⁷ was also published. This web questionnaire was filled by 441 actual electric vehicle users, i.e. with a response rate over 70%, and it focused mainly on user experience and attitudes towards the charging network. To highlight some findings, during winter months (November–March) electric car users typically drive 30–50 km a day, in the summer season more. Around the year, private car owners tend to undergo longer distances per day than the social workers. According to the electric cars users' experience, the effective drivable mileage is most influenced by reducing heating or optimising the driving speed. Corporate representatives give high significance also to travel planning.

Although internationally electric cars have been recognised mostly as a competitive option in urban areas, the Estonian strategy has been to create a spatial balance and diminish developmental differences across the whole country.¹⁸ Therefore, it was decided to build the nationwide quick charging network that ensures optimal transport also in outermost regions by using appropriate modes of transport. According to the users' survey, around three-quarters of both the private and corporate electric car users name the normal (or so-called slow) charger as the main charging point, either at work or at home, and this is usually done during night. Only 5% named the cross-national quick charging network as the main charging point. Approximately half of the users are satisfied with the existing national quick charging network, 38% can cope with it but would like improvements, and another 11% are not satisfied with the current situation at all. Private users tend to be generally more satisfied. The result is interesting also because of the conflict—quick charging is usually not the main option, however, people are generally satisfied with their distribution. Hence, the further increase in the number of quick charging points should not be the first priority given the current electric vehicle penetration rate, but there should be more slow chargers available next to office buildings, etc.

The survey also shows that approximately 73% of electric car users in Estonia are generally satisfied with the car itself; the main drawbacks come from the harsh climate and road conditions during Estonian winters. As expected, the most negative aspect that was pointed out in the survey is the small battery capacity and consequent low mileage. Surprisingly enough, even 97% of private electric car owners are rather satisfied or completely satisfied. The

same tendency also occurs from the evaluation of car equipment levels, 85% of users consider it at least normal or sufficient. The most desired extras are automatic speed control (maintaining a steady speed would increase mileage) and an additional (other than electrical) heating device. The electric car is mostly valued due to good controllability and manoeuvrability (29%), quietness and compact size (20.2%), and good acceleration (18.8%). Low car maintenance costs are also important, particularly for private car owners. By answering one of the most powerful customer survey questions, 43% of all electric car users, and as much as 92% of the private owners, say that they would recommend electric cars to others.

In general, we think that the above results are not so surprising because according to the Estonian Human Development Report,¹⁹ Estonians are quite eager to try out new technologies and to make the best use of them. A fair share of Estonians believe that the improvement of education and the spread of innovative thinking leads to the improving competitiveness of economy and consequently to a rise in people's incomes and wellbeing.

In order to complement the big picture, the two types of data collection (the feedback mechanisms of the living lab and the user survey) complement each other well. The statistics about the popularity of different vehicle models show that the biggest share (53%) belongs to the Mitsubishi i-MiEV, but when we deduct the free fleet allocated to social workers, the Nissan Leaf is the incontestable market leader. Similarly to the early doubts of the customers, the car distributors were hesitating as well. Therefore, although the Nissan Leaf is not considered to be technically much better than its main competitors, the courage to take action at early stage now pays off.

To implement an experimental programme like this might not be feasible in all countries. If there is no such extraordinary funding resource available, such as Estonia had with the income from excess CO₂ quotas, it is still a relatively risky project to take up. Spending taxpayers' money for implementing similar projects might not be a very popular decision and politicians would probably not be eager to take that risk. Since Estonia was able to use the funding from excess CO₂ quotas, the implementation of the pilot programme is considered to be received for free, and people are therefore most likely also not so critical about some initial drawbacks.

However, together with designing the programme and deciding on the particular mix of incentives, the protection phase-out process should be planned as well. As we can observe from Figs. 6 and 7, the trajectory of electric vehicles' registrations in Estonia has hypes and steep declines. As the funds for the purchase grant are now finished, and there is no clear vision from the government about how to continue, the future of electromobility remains unclear. At the moment the prices of electric vehicles are still not competitive, but quick developments in the battery technology might change the situation. If so, then the countries with experiences from local pilot projects will be in the preferred situation for large-scale uptake of electromobility, if not, then without follow up activities from the government, the usefulness of the whole pilot programme may become questionable.

In this particular case, in a way this extraordinary funding source put Estonia into a forced position—it was necessary to make some kind of investment decision or deal. At the same time, the available funding also set some limits to the implementation of the pilot programme, e.g. to acquire Mitsubishi i-MiEVs for the social workers' demonstration fleet, without an option to choose between the other brands or models.

¹⁷ Electric car users survey. Faktum-Ariko, 2013 [http://elmo.ee/public/Elektriautode_kasutamise_uuring_ELMO2013.pdf].

¹⁸ Estonian Transport Development Plan 2006–2013 (Transpordiarenduskava). [<https://www.riigiteataja.ee/aktiis/0000/1278/4604/12784610.pdf>].

¹⁹ Estonian Human Development Report, 2013 [<http://www.kogu.ee/olemus-ja-roll/eesti-inimarengu-aruanne/eesti-inimarengu-aruanne-2013>].

If a country (or region) has its own automotive industry, then this may also be the main driver instead, and the matrix of objectives (Fig. 1) would change accordingly. The same applies to companies supplying associated products and services (batteries, chargers, ICT solutions, etc.).

As the political motivation for supporting certain kinds of innovations depends also on the local resources, the positive environmental impact of electromobility would be questionable when electricity would not be produced locally and from renewable sources. Therefore, the essential base for justifying support for wider diffusion of electric vehicles has been the increase in the share of renewable electricity. Historically Estonia has covered all its electricity needs from using locally extracted oil shale. Due to extensive governmental support for large-scale wind parks during 2007–2012,²⁰ the share of electricity produced from renewable sources has increased to 13% in just one decade, and the trend has been going upwards also in 2013–2014. This ensures that at least in the near future there is enough renewable electricity available to meet the needs of increasing popularity of electric cars.

4. Conclusions and policy implications

There are a number of actors and stakeholders who are involved or affected by these kinds of transformative innovations and each one of them has their own interests and motivations. The government must be like a conductor who puts these sometimes conflicting interests under one roof, so that eventually everybody in the society would benefit from it. The role of the government is also to find those interest groups who are motivated enough to carry on with the projects even if at some point the financial incentives will cease. In addition to the direct incentives, the important role of the government is to guide public opinion and therefore marketing campaigns have also been an important part of the Estonian pilot programme. However, a powerful way to spread positive user experience is ‘word-of-mouth’ marketing by the first users. We believe this would be most efficient to help overcome the persisting misconceptions; however, it will take some time.

Despite the fact that the Estonian subsidy for purchasing an electric car was among the most generous in Europe, at the beginning the actual demand was not as high as expected and it took time to build consumers’ trust. Today we can make first conclusions about the experiences from the Estonian pilot programme. Firstly, it is clear that thanks to the data collected throughout the pilot programme, the battery and car manufacturers will gain important input to improve their products. The Estonian climate is suitable for testing electric cars in quite extreme winter conditions, the weaknesses of technical solutions should be easily identifiable. Thus, when using it as a test bed, these technical solutions that work here should most likely also work elsewhere. Secondly, due to the fact that Estonia has a low population density, charging network planners can get valuable insights for building optimal cross-national networks. Thirdly, the learning aspect also comes out from testing the policy instruments for fostering radical environmental innovations. Additionally, from an entrepreneur’s perspective it is also a unique opportunity for validating new business models, with or without the governmental support. In conclusion, the main lessons from the Estonian electromobility pilot programme can be summarised as follows:

- For fast market uptake of radical (eco) innovations the active role of government is crucial;
- Radical innovations that involve multiple regimes require a systemic approach in order to avoid the ‘chicken and egg’ problem;
- Together with creating the incentives, the protection phase-out process should be planned as well;
- New business models that offer experience with new technologies, without requiring immediate ownership, should also be supported in order to enhance consumer acceptance;
- Participating in market pilot projects gives valuable feedback for companies before heading to export markets.

The viewpoints and feedback mechanisms explained in this article provide a solid base for further analysis of empirical data. The first insights about what has gone as expected and where the drawbacks have been experienced during the Estonian pilot project will need to be verified by longitudinal data sets and international comparison.

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²⁰ Estonia to Retract Pledge on Wind Energy Subsidy Limits. Bloomberg 10.01.2013. [<http://www.bloomberg.com/news/2013-01-10/estonia-to-retract-pledge-on-wind-energy-subsidy-limits.html>].

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